THE MECHANICAL SEAL

FRIEND OR FOE?

BY

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Summary

The mechanical seal is an important but often neglected piece of equipment. This article discusses some of the reasons for premature failure and describes the current development programme within the Ship Department. Some practical "Do's" and "Don'ts" are offered to help the user and maintainer to prolong the life of seals.

The author has concentrated on sea-water applications as this appears to be the area containing the largest number of problems in the achievement of effective, durable sealing.

Introduction

All mechanical seals leak. This statement is likely to produce vigorous agreement from all marine engineers and conjure up visions of flooded bilges but it is, in fact, a design requirement. The faces of a mechanical seal do not normally make direct contact with each other when the seal is rotating in fluid. The faces are separated by a thin fluid film typically only one tenth of a thousandth of an inch thick. Zero leakage is usually accepted as being less than 0·005 cm^3 per hour so that, as far as these seals are concerned, leakage is a matter of degree rather than of fact.

The mechanical seal evolved from consideration of methods of improving rotating shaft 'glands'. The radial face 'mechanical' seal was initially developed for the chemical industry where the integrity of the seal is very important. The majority of modern pumps are fitted with them and the same concept has been applied to stern tube/shaft seals, other rotating plant and even pumping units of the Transalpine pipeline.

The concept makes use of a rotating, floating ring which is axially loaded to rub against a fixed counterface (or vice versa), the axial leakage path being sealed by an O-ring, PTFE wedge, bellows or similar device. The choice of material for the faces is important and, of course, depends upon the application. At present the most common combination for use in sea water (e.g. fire pumps) in the R.N. is carbon rubbing on lead-bronze but this is being replaced by a new material which will be described later.

The problem

Failure statistics on mechanical seals, particularly in sea water, are fairly alarming. A survey of data from nineteen *Leander* Class frigates over a thirty-month period indicated that, on average, each ship spent four man-hours per month replacing defective seals in fire pumps alone and one ship replaced twenty seals in two pumps over a period of twenty-seven months. FIG. 1 shows what can only be described as a catastrophic failure.

Whilst these sort of failures can quickly alert the designer to the existence of a problem, diagnosing and correcting the trouble is a different matter altogether because the precise mechanism of failure is often elusive. Even experts have difficulty establishing the exact cause of failure on many occasions and it is not surprising that the hard-pressed maintainer is rarely able to report much more than 'mechanical seal leaking—replaced'. Additionally, mechanical seals are a very minor item in his total machinery fit. The designer is thus limited for detailed feedback to information from test rigs. Whilst every effort is made to make realistic test rigs, artificial results can be produced from the simulation of on-board conditions.

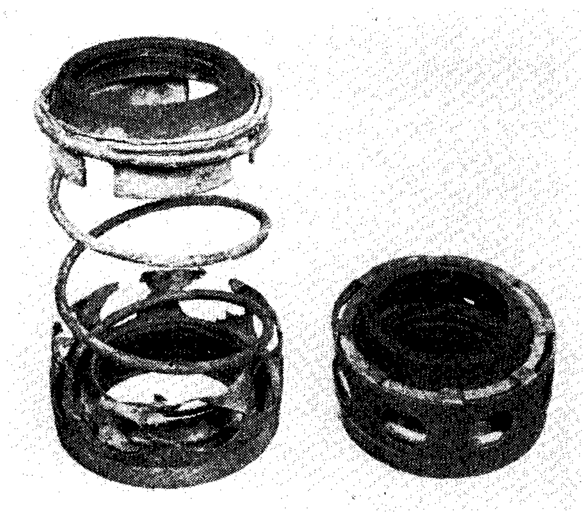

FIG. 1—A CATASTROPHIC FAILURE

Some Reasons for Failure

Discussions with maintenance and repair authorities suggest that seal life is generally satisfactory provided that the seal is fitted correctly and operated in the correct environment. This, however, is easier said than done. The performance and life of mechanical seals are sensitive to many factors which can loosely be divided into three areas—design considerations, manufacturing tolerances, and operating conditions. TABLE I lists some of the more important factors and indicates their effect on performance and life.

Thus, given adequate quality control (a pretty sweeping assumption in itself), three factors—face load, mechanical distortion, and thermal distortion—can be affected by operating conditions which are outside those envisaged by the designer with resultant deterioration in seal performance or a reduction in life.

TABLE I—*Factors affecting the performance and life of mechanical seals*

Factor	*Is the performance or life affected by:*		
	Design considerations?	*Manufacturing tolerances?*	*Operating conditions?*
Seal face flatness	Yes	Yes	No
Face load	Yes	Yes	Yes
Seal materials	Yes	No	No*
Sliding speed	Yes	No	No*
Pressure across seal	Yes	No	No*
Mechanical distortion	Yes	Yes	Yes
Thermal distortion	Yes	No	Yes
Fluid viscosity	Yes	No	No*
Surface tension	Yes	No	No*

* These factors should not affect performance if the seal is chosen correctly for its particular application.

Face Load and Mechanical Distortion

Marked changes in the face loading of a mechanical seal from its design condition will result in excessive leakage, due either to inadequate sealing pressure if the face loading is too low or to rapid wear and failure if the face loading is too high. Mechanical distortion can have similar effects. FIG. 2 shows the result of excessive face loading of a lead-bronze seat probably caused by incorrect location of one of the faces when the seal was installed. The groove cut in the face is about $\frac{3}{16}$-in. deep.

Incorrect fitting is probably a major cause of failure in these modes and successful fitting of mechanical seals requires some expertise. Training establishments have to cover an enormous syllabus of which mechanical seals form only a minor part and so only a limited time can be devoted to them. Practical training has therefore to be given on the job and this also is limited by overriding requirements such as the time available, reduced manning standards, smaller ME department complements in new ships and high ship-usage rates.

The whole situation can be further aggravated by the physical problems of installing the seal. A classic example is the motor-driven fire pumps in the *Leander* and County Class, where the new seal has to be offered up into its housing from below, virtually blind, and then the impeller replaced without disturbing the delicate location of the seal components. The seal loading is achieved by the impeller nut. Many older pump units have mechanical seals installed in a stuffing box originally designed for gland packing. Other units have a well-designed housing and mechanical seal but, regrettably, each was designed in isolation from the other and often the cheapest available seal is fitted. It is important, therefore, that mechanical seals are properly designed into a pump and this is now being done. Furthermore, to assist

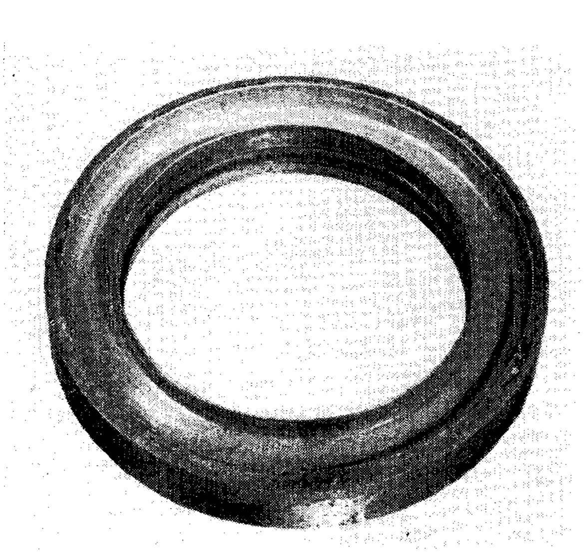

FIG. 2—A BADLY WORN LEAD-BRONZE SEAL FACE

with fitting, it is current policy to supply replacement seals as complete units. The saving in man-hours resulting from the reduced number of early failures of part-worn components easily compensates for the higher cost of replacement parts. Hopefully, as a side effect, this policy also ensures that a piece of the assembly is not left out. Defect returns show that this does happen!

Thermal Distortion

Thermal distortion can result from excessive face load and mechanical distortion already discussed. Many seal designs incorporate a flushing/cooling fluid supply. If this is shut off or becomes blocked (or even disconnected to enable a pressure gauge to be fitted, as was found on one occasion) then overheating can lead to rapid failure through face damage or seal distortion.

Dry running is a definite cause of many seal failures and its effect on the seal is to replace the fluid between the seal faces with air or hot vapour so that the system of hydrodynamic lubrication collapses. This is bound to cause catastrophic failure of the seal immediately or within a short time. The condition can be initiated by air locking in the vicinity of the seal which is normally at the 'highest point' of a vertical pump. Fire pumps are particularly prone to drawing in air through the suction system when a ship is under stern-way and, needless to say, any pump will experience a similar effect if it is run with its suction shut. It is essential that seal chambers are properly vented. All instances of regular hot running should be reported.

In common with any precision-made machinery components, mechanical seals are easily damaged by sand, corrosion products and other abrasives. Not only can the seal faces be damaged but these types of particles can also jam the floating face or clog the spring; this again emphasizes the importance of maintaining flushing supplies. In some cases it is likely that flushing water contains abrasives, particularly sand, and the only effective solutions are:

(*a*) a separate filtered flushing supply to the seal,

(*b*) more durable rubbing faces.

Development

Three lines of approach are currently under investigation:

Face Materials

The Admiralty Engineering Laboratory (AEL) have evaluated various combinations of face materials. The seals were run in pairs in salt water and on completion of each trial (about 4 000 hours) were examined for wear and corrosion. Test materials included carbon, tungsten carbide, chrome oxide, hot-pressed silicon nitride, and boron carbide in various combinations. The results, supported by tribological tests at the Admiralty Materials Laboratory (AML), indicated a sprayed coating of chrome oxide (a ceramic with the trade name LC4) deposited onto a phosphor-bronze seat and running against babbitt-loaded carbon to be most suitable. This material combination is in service in submarine salt-water pumps, new design pumps and is being progressively fitted to existing 'problem' pumps (such as fire pumps in *Leander* and County Class) which suffer from high wear rates in service.

In parallel, research is also going on into stern-tube/shaft seals where there is some read across to the smaller pump applications. In the commercial field, the use of solid ceramics as a face material is an area which is showing promise.

Modular Seals

A modular seal is a pre-loaded assembly which is fitted, as a complete module, onto the shaft to be sealed. It eliminates delicate fitting problems and protects the seal faces from mechanical damage as it is never opened up. It is simple to position and secure in place. One design in particular also isolates the axial-loading springs from the working fluid thereby eliminating a possible source of trouble. In all the designs, the face loading is pre-set and this is a considerable advantage.

A market survey has been undertaken to select a unit or units for evaluation at AEL. If this is successful, the introduction of this type of seal into service should reduce the incidence of seal failures and, although the initial cost may be higher, it should prove cost effective in the longer term.

Soft-Packed Seal

A new type of soft-packed, radially-loaded shaft seal is under investigation. It consists of a split shell of rubber-cased soft packing, a stuffing-box adaptor, two sealing gaskets and a seal plate incorporating a grease nipple and a pressure relief valve. Radial hydraulic loading of the soft packing is achieved over its full length by the application of grease pressure and compression prevents leakage along the shaft. The seal is cheap and easy to renew and has been installed in a frigate fire pump for a trial period. Initial results were not up to expectations but a modified version is now to be tried with more hope of success.

Some "Do's" and "Don'ts" for Users and Maintainers

Do:

(*a*) Replace failed seals with a complete new unit. The only exception to this is the Flexibox type RCA which is supplied as three components to avoid unnecessary disposal of seal-plates which do not wear.

(*b*) Keep seals wrapped until they are to be fitted.

(*c*) Treat seals with care; the faces are delicate and are finished to a high standard.

(*d*) Check shaft or sleeve diameter.

(*e*) Ensure that the shaft is free from vibration.

(*f*) Check the shaft for ovality.

(*g*) Use metal polish on the shaft in way of wedge rings, O-rings, etc. The seal manufacturer's recommendations for shaft finish vary from 5 to 20 micro-inches CLA.

(*h*) Check shaft run-out.

(*i*) Check for correct axial location of the seal seat with reference to the stop or collar on the shaft.

(*j*) Check that the end face of the stuffing box is true and square with the shaft

(*k*) Fit seals carefully following the fitting instructions closely (*BR 3001*).

(*l*) Use grease, Teepol, etc. to aid assembly.

(*m*) Ensure that anti-rotation pins and similar fittings are fully located. Failure to do so is a common cause of rapid face wear.

(*n*) Check for correct handing of seal springs. Rotational effects should tend to lengthen the spring.

(*o*) Ensure that the seal venting arrangements (where fitted) are operating correctly.

Don't:

(*a*) Run the pump dry. The only good mechanical seal is a wet one.

(*b*) Allow grease to get on the seal faces.

(*c*) Expect mechanical seals to work for long on misaligned or bent shafts.
(*d*) Fit sealing rings over sharp edges, burrs, or onto poorly finished surfaces. Sleeves or shaft shoulders should be chamfered.
(*e*) Unload *all* your mechanical seal work onto the FMU. Ship's staff expertise is invaluable and can only be developed on the job.

Acknowledgement

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